Reply to "Comment on 'Adiabatic excitation of longitudinal bunch shape oscillations'"

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Response is made to J. A. MacLachlan's preceding Comment [Phys. Rev. ST Accel. Beams 4, 017001 (2001)]. We are gratified to see that high quality simulations, as presented by MacLachlan, verify our experimental results.

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I. INTRODUCTION

MacLachlan [1] takes up the suggestion we offered in our original manuscript to use multiparticle tracking to simulate our experiments. He is able to perform simulations which agree well with our experiments. We are grateful for his work and offer our sincere thanks to him. In this response we will explain the merits of our technique with respect to other techniques.

II. TECHNIQUES FOR SHORTENING BUNCHES

In his Comment, MacLachlan [1] points out that we had not offered any discussion of the merits of our technique with respect to other techniques. Our original motivation was to achieve shorter bunches without compromising longitudinal emittance. We will review here three possible methods of achieving shorter bunches, outside of the technique we utilized. The first method (method 1) is simple, just adiabatically raise the voltage on the rf cavities. In this case the bunch length will become shorter by the fourth root of the ratio of the voltages. A 120 nsec bunch could be shortened to about 100 nsec in going from 100 to 200 kV. Our technique achieves shorter bunches by roughly the square root of the average to the maximum voltage. In this case, our 120 nsec bunch can be shortened to 85 nsec. A second technique (method 2) is to adiabatically lower the rf voltage to create a long bunch and then to snap the rf voltage back up again. After one quarter of a synchrotron period the bunch would be shorter and could be extracted. This works well if there are no remaining bunches. If there are any remaining bunches after extracting this first bunch and no other rf manipulations are performed, then they will filament out (since the snap up is not adiabatic). In a third technique (method 3) the rf is phased so that the beam sits on an unstable fixed point for a short period of time. The rf phase is then jumped back to the stable region with the gap volts set correctly to accept the stretched out beam. Again one waits for the orientation of the phase space to rotate to its shortest width in time and kick the beam out [2]. These methods are all nonadiabatic and other manipulations must be performed to minimize filamentation. What makes our method unique is that the driven oscillations can be sustained indefinitely, thereby providing a short bunch state for a long period. The other three techniques do not provide the short bunch state for a long period (the manipulations would have to be repeated to reestablish the short bunch state). In the situation when bunches are extracted one by one, we need a technique that shortens the bunches, preserves the emittance, and provides a sustained short bunch state. The method used for fast extraction in the alternating gradient synchrotron (AGS) at Brookhaven National Laboratory (BNL) is a multiple, single bunch, extraction scheme designed to deliver bucket-to-bucket transfers between the AGS and the BNL relativistic heavy ion collider (RHIC). In this system, single bunches are extracted from the AGS every 33 msec. For the g-2 experiment [3], the AGS ran on a harmonic of 6, and so all six bunches were extracted in 165 msec. By modulating the rf voltage with a frequency that was an integer harmonic of the extraction frequency (30 Hz), and near twice the synchrotron frequency, we were able to deliver to the experiment six very short bunches while preserving the longitudinal emittance of each bunch [4].

Although we concur with MacLachlan on his remarks regarding the development of new codes to simulate our experiments [1], we elaborate here further considerations on this subject. Using a highly refined simulation code that can incorporate all the physics required to model an experiment is required when analytical methods are not possible. Nevertheless, one adds complexity to the model only as required by the complexity of the experiment and to study finer-grained structures. For our experiments we developed a simple model which allowed us to focus on our specific problem. The results of our simple model agree very well with our experimental data. MacLachlan also acknowledges in his Comment that he is able to simulate our experiments without adding any great complexity. The agreement between the two simulations and our data is excellent. Results of our simulations were presented at the ICAP 2000 Conference [5].

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